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Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,286,878,** on October 15, 1999, by **FANTOM TECHNOLOGIES INC.,** assignee of Wayne Ernest Conrad, for "Method and Apparatus for Automatically Optimizing the Power Consumption of an Electric Motor".

CA00/1183

PRIORITY DOCUMENT

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October 23, 2000

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ABSTRACT OF THE DISCLOSURE

A method and apparatus are provided for adjusting and modulating an electric power supply to an electric motor. The power supply is modulated by a pulse train. Parameters of the pulse train, such as frequency, pulse width and voltage, can be modified in accordance with an algorithm, to improve the motor performance. At least one parameter indicative of motor performance, such as power supply for the motor or motor speed, is monitored, to enable adjustment of the parameters of the pulse train modulating the power supply, thereby to achieve desired motor performance.

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BERESKIN & PARR

CANADA

Title: METHOD AND APPARATUS FOR AUTOMATICALLY OPTIMIZING THE POWER CONSUMPTION OF AN ELECTRIC MOTOR

Inventor: Wayne Ernest Conrad

Title: METHOD AND APPARATUS FOR AUTOMATICALLY OPTIMIZING THE POWER CONSUMPTION OF AN ELECTRIC MOTOR

FIELD OF THE INVENTION

This invention relates to electric motors. This invention more particularly is concerned with the method and apparatus for optimizing the power consumption of an electric motor.

BACKGROUND OF THE INVENTION

There are many applications today in which electric motors are employed. The energy consumption of motors for pumping gases and liquids accounts for over one-quarter of all electricity consumed in the world today. There are known a number of techniques, employing pulse width modulation, to control the power consumption of motors; such techniques have had modest success and generally are provided to control motor power or speed with little or no regard to improving motor efficiency.

The intention of the present invention is to significantly reduce the power consumption of electric motors, particularly in such applications as the movement of air and pumping of liquids. Research by the inventors has found that these types of electromechanical assemblies have a natural resonance. Additionally, it has been found that when the electrical signal or power supplied to the device is conditioned, so as to provide energy in synchronism with natural resonant frequencies of the motor and associated equipment, the power required to produce the desired work is significantly reduced.

Additionally, it is believed this invention has general applicability to any electrical power consuming circuit or device which shows similar characteristics. That is, it is applicable to any device which shows some resonant characteristics, and where providing the power signal as a pulse train with suitable characteristics of voltage, frequency and pulse width, can improve the efficiency, in effect energy coupling or transfer from

the electrical power supply to the circuit or device is enhanced. This in turn can reduce the power energy required to deliver the desired work.

SUMMARY OF THE INVENTION

The present invention is based on the realization that the excitation of an electric motor, either a DC or AC motor, can be improved by providing the signal as a pulse train, with the characteristics of voltage, frequency and pulse width, modulated to optimize a power delivered. This can be applied to either AC or DC motors.

In accordance with a first aspect of the presnet invention, there is provided a method of controlling power supplied to an electric motor, the method comprising:

(1) providing an electric power supply;

(2) modulating the electric power supplied with a pulse train;

(3) supplying the pulse train to the electric motor;

(4) monitoring at least one of the power supply to the motor, the speed of the motor and other parameters indicative of motor performance; and

(5) modifying at least one of the frequency, pulse width and voltage of the pulse train, to achieve a desired motor performance.

Preferably, the method includes providing an algorithm relating motor performance to voltage, frequency, and pulse width of the pulse train, and modifying at least two parameters of the pulse train in accordance with the algorithm.

The method can also include monitoring the performance of the motor, and performing an optimization routine, to optimize the motor performance, whenever the motor performance varies outside a preset range of parameters.

The method can include varying the pulse width and the voltage of the pulse train as said two parameters, or the frequency and voltage of the pulse train, as said two parameters, or the frequency and

pulse width of the pulse train, as said two parameters. Alternatively, the method includes varying the frequency, pulse width and voltage of the pulse train.

Another aspect of the present invention provides an apparatus comprising:

an input for an electric power supply;

a first electronic control unit connected to the input, for receiving the electric power supply, for generating a pulse train to modulate the power supply and having an output for a power supply modulated by the pulse train, the output being connected to an electric motor in use; and

a second electronics control unit connected to the first electronics control unit and having means for detecting at least one parameter indicative of motor performance, whereby the second electronics control unit enables adjustment of the pulse train generated by the first electronics control unit, to adjust motor performance.

Preferably, the second electronics control unit includes means for measuring the power supplied to the motor and means for detecting the speed of the motor, for example means for detecting the current supplied to the motor.

Advantageously, the second electronics control unit includes an input for enabling an operator input of desired motor performance.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawing, which shows a preferred embodiment of the present invention, and in which:

Figure 1 is a schematic view of an apparatus and an electric motor in accordance with the present invention; and

Figure 2 is a graph showing an exemplary pulse train over one period.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In Figure 1, there is shown an apparatus comprising a voltage source 1 connected to a first electronics control unit 2, by wires 3 and 4. The electronic control unit 2 is in turn connected by one wire 6 directly to a motor 5, and by wires 7 and 8 and an inductor 9, in series, to the motor 5.

A second inductor 10 is provided, inductively coupled to the inductor 9, and connected to a second electronic control unit 11 by wires 12 and 13. The second electronic control unit 11 receives power through wires 20 and 21, connected to the first electronic control unit 2. Additionally, the second electronic control unit 11 provides control information, detailed below, to the first electronic control unit 2 through the wires 20, 21.

To monitor the motor speed, a magnet 14 is mounted on the rotating shaft 15 of the motor, and is magnetically coupled to an inductor 16. The inductor 16 is connected by wires 17 and 18 to the second electronic control unit 11. Thus, rotation of the shaft 15 and the magnetic 14 generate a pulse train from the inductor 16, which is detected by the second electronic control unit 11, and the frequency of this pulse train is proportional to the speed of the motor 5.

A control input for the electronic control unit 11 is indicated schematically at 19. Although shown as a single lead, it will be understood that this could comprise a multiple lead input. It enables input of desired or intended characteristics for the motor behaviour, for example, speed and power supplied to the motor.

In use, the second electronic control unit 11 receives signals indicative of motor speed and current supplied to the motor. The control unit 11 is also pre-loaded with an algorithm relating motor performance to the three main parameters of a pulse train, namely frequency, pulse width and pulse height (or voltage). In dependence on this algorithm, sensed motor conditions or load and the input at 19, the electronic control unit 11 sends control signals to the first electronic control unit 2, to cause the control unit 2 to deliver a pulse train to the motor 5, which pulse train will

give the desired motor performance.

The pulse train comprises a set cycle of pulses, for example, a plurality of pulses that may be of the order of 10 pulses or more longer. Pulses within the cycle can vary, in terms of their pulse width and pulse height. This cycle is repeated continuously, to generate the pulse train, as detailed below in relation to Figure 2.

This invention is believed to have particular applicability to vacuum cleaners. As such, a motor for a vacuum cleaner is attached to a fan, for drawing air through the vacuum cleaner, so as to produce the desired vacuum effect. What the inventor has realized is that the individual blades of a fan commonly throw off a series of vortices. In effect, a boundary layer continually builds up, separates and collapses on one side of each blade. This leads to much wasted energy.

The inventor has discovered that if the supplied signal to the motor is configured so as to cause acceleration just prior to collapse or delamination of the boundary layer, and to decelerate just after delamination, then the boundary layer does not in fact completely collapse, but instead simply reduces or thins down. In effect, this reduces the vortex energy thrown off from the blade, and hence significantly reduces energy losses. Accordingly, the algorithm for the pulse train for a vacuum cleaner should be developed, with this in mind. This is done simply by running a series of tests or experiments on a complete vacuum cleaner, which will allow for any effects which will alter the power consumption of the motor.

Figure 2 shows exemplary pulse wave forms over a period 20. Within this period 20, there are 5 individual pulses, labelled 21, 22, 23, 24 and 25. Following each pulse, there is a respective pulse interval, labelled at 21a, 22a, 23a, 24a and 25a. In this example, these intervals have the parameters given in the following table and shown in the drawing.

TABLE 1

Pulse Number	Pulse Voltage	Pulse Duration	Pulse Interval
21	1.3	0.7	4 ms
22	1.4	0.8	5 ms
23	1.5	0.9	6 ms
24	1.6	0.1	7 ms
25	1.9	0.1	10 ms

As this table shows, within the period 20, all the parameters of the pulses, namely frequency (i.e. inverse of the pulse interval), pulse width or duration, and pulse height (voltage) are varied. This gives a distinct pulse profile for the period, and this is repeated in following periods. In general, depending on the particular application, it may not be necessary to vary all three parameters, and it may be sufficient to vary just two of them, or even just one of them, with the other(s) being kept constant. Additionally, it will be understood that the absolute magnitude of each of these parameters can vary greatly depending upon the actual application. Also, a variety of pulse profiles can be used.

It is to be appreciated that the pulse profile detailed above was developed primarily for a battery charge/discharge aspect of the present invention, the subject of separate simultaneously filed applications by the same inventor. For use with an electric motor suitable pulse train characteristics can be selected.

CLAIMS:

1. A method of controlling power supplied to an electric motor, the method comprising:

(1) providing an electric power supply;

(2) modulating the electric power supplied with a pulse train;

(3) supplying the pulse train to the electric motor;

(4) monitoring at least one of the power supply to the motor, the speed of the motor and other parameters indicative of motor performance; and

(5) modifying at least one of the frequency, pulse width and voltage of the pulse train, to achieve a desired motor performance.

2. A method as claimed in claim 1, which includes providing an algorithm relating motor performance to voltage, frequency, and pulse width of the pulse train, and modifying at least two parameters of the pulse train in accordance with the algorithm.

3. A method as claimed in claim 2, which includes monitoring the performance of the motor, and performing an optimization routine, to optimize the motor performance, whenever the motor performance varies outside a preset range of parameters.

4. A method as claimed in claim 2 or 3, which includes varying the pulse width and the voltage of the pulse train as said two parameters.

5. A method as claimed in claim 2, or 3, which includes varying the frequency and voltage of the pulse train, as said two parameters.

6. A method as claimed in claim 2 or 3, which includes

varying the frequency and pulse width of the pulse train, as said two parameters.

7. A method as claimed in claim 1, 2 or 3, which includes varying the frequency, pulse width and voltage of the pulse train.

8. An apparatus comprising:

an input for an electric power supply;

a first electronic control unit connected to the input, for receiving the electric power supply, for generating a pulse train to modulate the power supply and having an output for a power supply modulated by the pulse train, the output being connected to an electric motor in use; and

a second electronics control unit connected to the first electronics control unit and having means for detecting at least one parameter indicative of motor performance, whereby the second electronics control unit enables adjustment of the pulse train generated by the first electronics control unit, to adjust motor performance.

9. An apparatus as claimed in 8, wherein the second electronics control unit includes means for measuring the power supplied to the motor and means for detecting the speed of the motor.

10. An apparatus as claimed in claim 9, wherein said means for detecting power supplied to the motor comprises means for detecting the current supplied to the motor.

11. An apparatus as claimed in claim 10, wherein said second electronics control unit includes an input for enabling an operator input of desired motor performance.

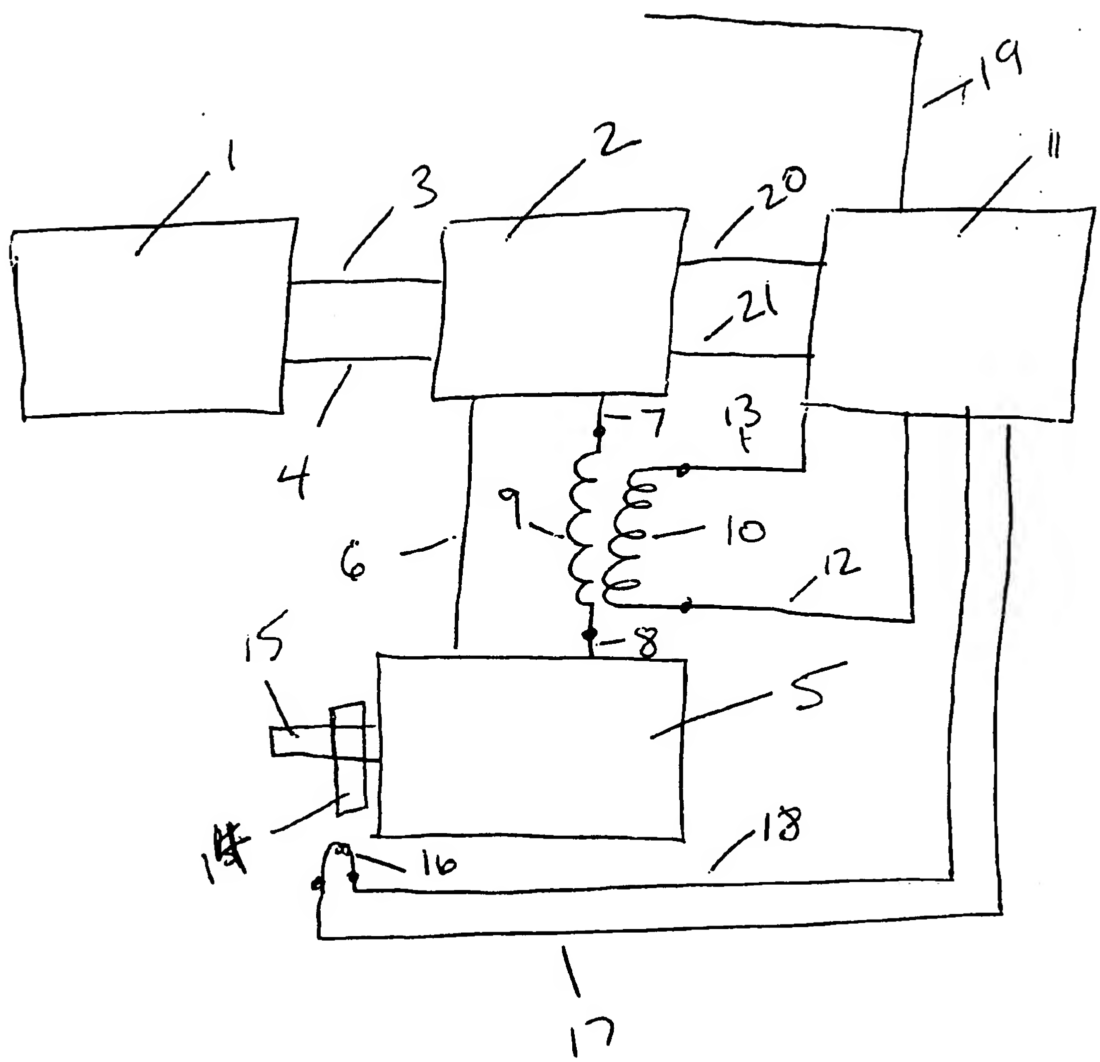

Figure 1

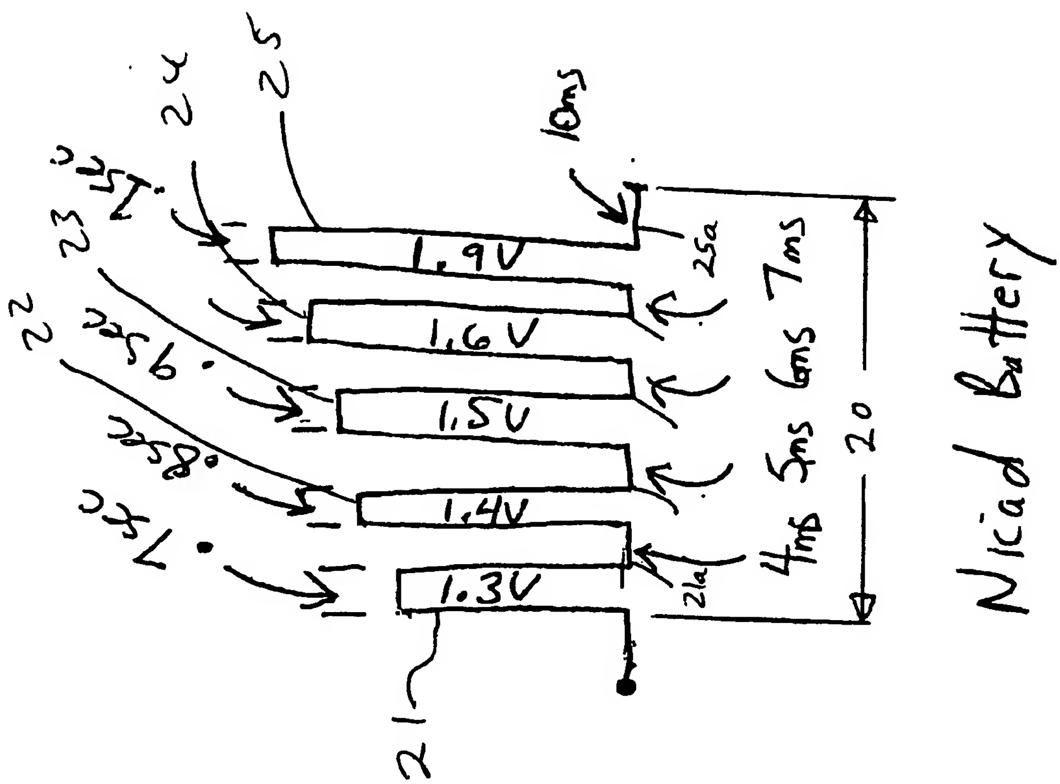
1.9V
1.6V
1.5V
1.4V
1.3V
25
24
23
22
21
25a
21a
10ms
4ms 5ms 6ms 7ms
20
.95sec
.85sec
.75sec
Nicad Battery

Figure 2